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WAR DEPARTMENT
AIR SERVICE
ENGINEERING DIVISION
McCOOK FIELD, DAYTON, OHIO
U. S. A.

REPORT

ON

THE PROBLEM OF LANDING.

BY

TECHNICAL DATA SECTION.

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To be returned to the files of the National Advisory Committee for Aeronautics.

WAR DEPARTMENT
ENGINEERING DIVISION
AIR SERVICE
McCOOK FIELD, DAYTON, OHIO

THE PROBLEM OF LANDING

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THE PROBLEM OF LANDING

(By E. Pistolesi)

I. The Horizontal Flight at Ground Level

The retarding force of the engine is designated by: $-K_x S V^2$ and the accelerating force by $\frac{-K_x S V^2}{Q/g}$.

Taking $Q = K_y S V^2$, we have: $\frac{dV}{dt} = -\frac{g}{\eta}$ -- I, η being the ratio:

$$\eta = \frac{K_y}{K_x}.$$

Transforming equation (I) to read

$$\frac{dV}{ds}\frac{ds}{dt} = -\frac{g}{\eta}$$

$$\text{(II)} \qquad \frac{d(V^2)}{ds} = -\frac{2g}{\eta},$$

also

$$\text{(III)} \qquad s = -\frac{1}{2g}\int_{V_1}^{V_2} \eta \, d(V^2).$$

when the integral ranges between the initial flying speed V and the final speed minimum V_2.

Equation (III) can easily be changed to read:

$$\text{(IV)} \quad s = \frac{Q}{2gS}\int \frac{1}{K_x} \frac{dK_y}{K_y},$$

as the integral with the initial and final K_y value.

Integrating either equation (IV) or (V) is much easier, especially when no graphic proceedings are used, providing that the polar equation remains within the initial and final points P_1 and P_2 respectively. (See Fig. 1). However, a simple equation curve can be substituted (parabola of ordinary n) of the following type:

$$\text{(V)} \quad K_x = K_0 + A K_y^{\,n}.$$

K_0 representing the value of the relative abscissae at the point where the

elongation of the curve substituted for P_1 and P_2 meets K_x.

Substituting into equation (IV) the integral obtained we have:

$$\text{(VI)} \quad s = \frac{Q}{2gSK_0 n} \log \frac{K_{x1} K_{y2}{}^n}{K_{x2} K_{y1}{}^n},$$

or

$$\text{(VII)} \quad s = \frac{Q}{2gSK_0 n} \log \frac{\eta_2 V_1{}^{2(n-1)}}{\eta_1 V_2{}^{2(n-1)}}$$

also (by n = 1) (VIII) $s = \dfrac{Q}{2gSK_0} \log \dfrac{\eta_2}{\eta_1}$.

(by n = 2) (IX) $s = \dfrac{Q}{4gSK_0} \log \dfrac{\eta_2 V_1^2}{\eta_1 V_2^2}$,

(by n = 3) (X) $s = \dfrac{Q}{6gSK_0} \log \dfrac{\eta_2 V_1^4}{\eta_1 V_2^4}$.

All preceding formulas approach the practice very close as may be seen from the following example:

Taking $K_{x1} = 0.00225$ $\quad K_{y1} = 0.020$ (point P_1)

$K_{x2} = 0.005$ $\quad K_{y2} = 0.047$ (point P_2)

The previous value gains from the polar in Fig. 1

$m = 1 \quad s = 13.2 \dfrac{Q}{S}$

$m = 2 \quad s = 13.8 \dfrac{Q}{S}$

$m = 3 \quad s = 14.1 \dfrac{Q}{S}$.

The difference in the various cases is not quite 7%. We may also post as average:

$$s = 14 \frac{Q}{S}.$$

$\frac{Q}{S} = 40$, when $s = 560\ m$, $\frac{Q}{S} = 50$, when $s = 700\ m$.

The preceding formula sounds a little complicated, and since we stop to consider the space s with great approximation, it is opportune to supply a more simple formula, that can be obtained to apply to the theory of mean value. So for equation (IV) we may write:

$$\text{(XI)} \quad s = \frac{Q}{2gS} \frac{1}{(Kx)_m} \log \frac{Ky_2}{Ky_1}$$

where by mean value $\frac{1}{(K_x)_m}$ we can simply say:

$$\frac{1}{2}\left(\frac{1}{K_{x1}} + \frac{1}{K_{x2}}\right).$$

Applying this to the previous example we find:

$s = 13.75 \frac{Q}{S}$, which also proves the admissibility of the proceeding.

But the formula more simplified and expressive when used to apply to the theory of mean value (equation) is then:

$$\text{(XII)} \quad s = \frac{(\eta)_m}{2g}(V_2^2 - V_1^2)$$

When also, P_1 and P_2 in regards to the angle of minimum traction (η = minimum) is approximately in line, we can write η_{min} ~~min.~~ in line of $(\eta)_m$ and we have then:

$$\text{(XIII)} \quad s = \frac{\eta_{min}}{2g}(V_1^2 - V_2^2)$$

or also: $\frac{V_1}{V_2} = \beta$;

$$\text{(XIV)} \quad s = \frac{\eta_{min}}{2g} V_2^2 (\beta^2 - 1)$$

Applied to the original example, we have:

$$s = 15.6 \frac{Q}{S},$$

a value somewhat greater than expected, but still approximately within 10%. The approximation naturally would be greater, unless P_1 P_2 are much restricted and in particular P_1 near the point of minimum traction.

Applying this to our practical example, we have:

V_2 (speed at landing) $=$ 32 m/sec.

η min $=$ 10

$V_1 = 1.5\,V_2 = 48$ m/sec.

also: $s = 640$ m.

It is interesting to note that equation (XIII) expresses in arrangement a dissipation of the live forces, the work in performing the gravity, unless the arrangement is accompanied by a constant inclination $\dfrac{1}{\eta \text{ min.}}$.

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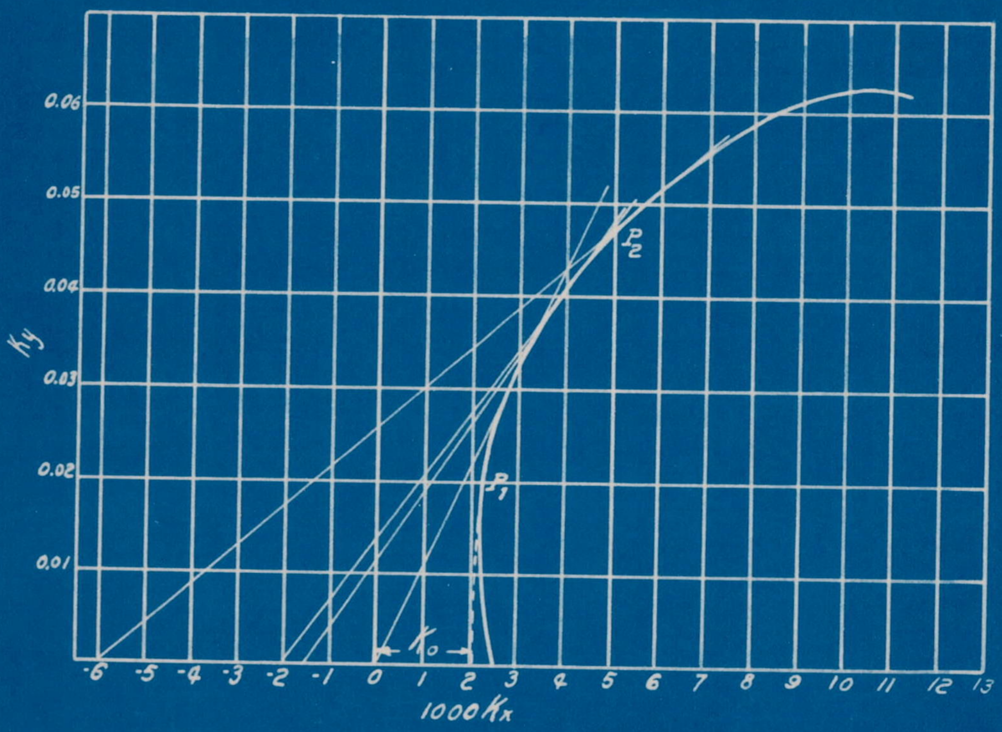
0.06
0.05
0.04
0.03
0.02
0.01
Ky
-6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10 11 12 13
1000 Kx
K0
P1
P2

Fig. 1.

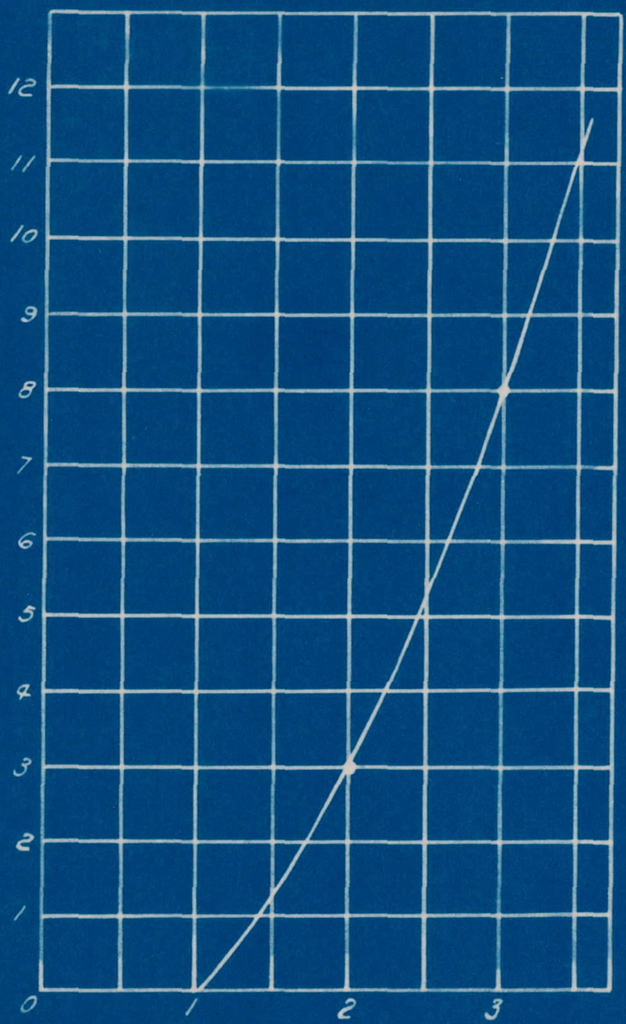

Fig. 2.